State of California
The Resources Agency
Department of Water Resources

DRAFT INITIAL PROGRESS REPORT ON THE EVALUATION OF PROJECT EFFECTS ON NON-FISH AQUATIC RESOURCES (SP-F1, TASK 1)

Oroville Facilities Relicensing FERC Project No. 2100

APRIL 8, 2003

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REPORT SUMMARY

Introduction: Aquatic macroinvertebrate and plankton communities are important components of the biological food web in Project waters. They are an important food source for fish species found within the Oroville Facilities and their community structure can provide general information on ecosystem health. The distribution and structure of non-fish aquatic resources in Project waters is associated with four broad categories: (1) physiological constraints (e.g., respiration, osmoregulation, temperature), (2) trophic considerations (e.g., food acquisition), physical constraints (i.e., habitat), and biotic interactions (e.g., competition, predation).

Purpose: The purpose of this study is twofold. The first purpose of this study was to document the status of existing macroinvertebrate and plankton communities and provide a description of the potential effects to these resources based on a review of the existing literature (Task 1). The second purpose of this study is site-specific and seeks to evaluate the operational effects of the Oroville Facilities (Task 2) on aquatic macroinvertebrates, phytoplankton, and zooplankton residing in the Project reservoirs and river habitats within the Study area.

Results and Products: A review of existing literature, field studies, and Project data was conducted to meet requirements for Task 1. The information is described in this initial progress report. In addition, the report contains a description of the condition of aquatic macroinvertebrate and plankton communities present in both the impounded and free-flowing freshwater habitats within the boundary of Oroville Facilities. The initial progress report also contains synthesized information on the effects of environmental and operational changes on macroinvertebrate and plankton abundance, distribution, and community structure in other aquatic systems. Key results from data collection efforts in the Study area are presented below.

Aquatic Macroinvertebrates:

- True flies (27%), mayflies (22%), and caddisflies (23%) made up more than 70% of organisms sampled from all sites combined.
- Collectors, filterers, and grazers were the most dominant functional feeding groups in the Study area from all sites combined.
- Highest taxa richess occurred in tributaries to Lake Oroville while lowest taxa richness occurred at the collection site upstream of the Feather River Fish Hatchery. In general, the collection sites in the Feather River below Oroville Dam indicated slightly lower taxa richness than upper tributaries, suggesting that the health of the assemblage below Oroville Dam is diminished compared to communities in the upper tributaries.
- The percentage of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa varied widely across all sites (5-84%); the highest EPT composition occurred at the Feather River site downstream of Project boundary and lowest at the site upstream of Feather River Fish Hatchery. Data indicates that the area near this site is highly disturbed.

- Macroinvertebrate diversity (i.e., Shannon Diversity Index) generally was higher in sites upstream of Lake Oroville compared to sites in the low flow reach of the Feather River or lower Feather River below the Thermalito Afterbay Outlet. Macroinvertebrate diversity was consistent with expectations for large rivers in the Sacramento-San Joaquin watershed.
- In the concurrent DWR/CSU-Chico collaborative study, overall invertebrate densities in the Feather River below the dam varied substantially between seasons but dominant taxa were similar to Feather River sites in the DWR study. Seasonal effects on macroinvertebrate communities in the Study area will be considered in more detail as data from collections in Spring 2003 becomes available.

Phytoplankton and Zooplankton:

- Overall, 43 different taxonomic groups of phytoplankton were identified from nine collection sites.
- Phytoplankton communities were dominated by families Bacillariophyceae (diatoms) and Cyanophyceae (cyanobacteria). Green algae (Chlorophyceae), golden brown algae (Chrysophyceae), dinoflagelates (Dinophyceae), and euglenoids (Euglenophyceae) also were collected. Comparative data for reservoirs was not obtained.
- Zooplankton have not been identified to date in available data reviewed from nine collection sites.

Potential Project Effects on Non-Fish Aquatic Resources:
Data from ongoing validation and enumeration efforts, in addition to future results from related studies, will provide additional information on environmental conditions that will be used to further evaluate the potential Project effects on non-fish aquatic resources in Project waters. Results from Task 2 (not yet completed) will be incorporated into a final study report scheduled for completion by June 2004. Relevant studies that are not yet complete but will be used to complete this effort include:

SP-F3.2 Evaluation of Project Effects on Non-salmonid Fish in the Feather River
SP-F5/7 Evaluation of Fisheries Management on Project Fisheries
SP-F10 Evaluation of Project Effects on Salmonids and their Habitat in the Feather River Below the Fish Barrier Dam
SP-G1 Effects of Project Operations on Geomorphic Processes Upstream of Oroville Dam
SP-G2 Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam
SP-W1 Project Effects on Water Quality Designated Beneficial Uses
SP-W2 Contaminant Accumulation in Sediments and Aquatic Food Chains

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1.0 INTRODUCTION

California Department of Water Resources (DWR) initiated the relicensing process for their Oroville Hydroelectric Project (Project) in 2001, FERC #2100. Based on stakeholder feedback derived through the collaborative process, the current or future mode of operation of Oroville facilities could affect aquatic non-fish resources. In the early stages of this process, DWR identified several priority issues, one of which is Project effects on non-fish aquatic resources. Thus, this study was conducted to evaluate Project effects on non-fish aquatic resources and respond to issues, concerns, and comments regarding the macroinvertebrate and plankton resources found in Project waters.

Aquatic macroinvertebrates and plankton communities are important components of the biological food web in the various impoundments within the Project area as well as the tributaries upstream from Lake Oroville and the Feather River downstream from Oroville Dam. Understanding the composition and structure of phytoplankton, zooplankton, and aquatic macroinvertebrate communities is important for understanding effects across trophic scales and for evaluating other primary licensing issues, such as the status of resident and anadromous fishes in the Feather River basin. This study, as well as other resource studies, is important for developing adequate existing information from which Project effects on resources can be determined and for developing appropriate protection, mitigation, and enhancement measures as the licensing process moves forward.

Phytoplankton, zooplankton, and aquatic macroinvertebrates are important components of the food web for anadromous and resident fish, as well as amphibians, birds, mammals, and other invertebrates. Many invertebrate species act indirectly as agents in nutrient recycling within stream and reservoir ecosystems (Black et al. 2001). Sierra Nevada streams and rivers historically had periods of high water in the winter and spring and low water periods in summer and fall. Invertebrate biomass in rivers was highest during high water periods and lowest during the summer and fall when flows were lower (Erman 1996). Invertebrate biomass in Sierra Nevada rivers was generally low during summer and fall because many insects are in the terrestrial stage or are in the egg or small larval stage (Erman 1996). Historical patterns of invertebrate biomass in the Feather River are not known. The construction of Oroville Dam inundated approximately 15,810 acres (maximum operating level) and changed the hydrologic cycle of the Feather River and its nearby tributaries. These changes affected invertebrate life cycles and communities that have evolved over time. Fluctuating reservoir levels, controlled flows downstream of the Project, sediment accumulation, and less-frequent scouring events have caused changes to the aquatic habitat within the Project area and likely have affected non-fish aquatic resources. Further, facilities at the Project may act as barriers and prevent either downstream movement or dispersal upstream (Vaughn 2002). These effects of dams on aquatic macroinvertebrates are consistent with environmental impacts associated with hydropower projects across the world (WCD 2000).

1.1 BACKGROUND INFORMATION

1.1.1 Statutory/Regulatory Requirements

Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission application for license of major hydropower Projects, including a discussion of fish, wildlife, and botanical resources in the vicinity of the Project. The discussion needs to identify the potential effects of the Project on these resources, including a description of any anticipated continuing effect for on-going and future operations. This study fulfills some of these requirements, by evaluating the potential effects on aquatic macroinvertebrate and plankton communities within the Project boundary.

1.1.2 Study Area

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided in Figure 1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir.

With the exception of a section of the Feather River in the low flow channel between the Feather River Fish Hatchery and about a mile upstream of the Thermalito Afterbay Outlet (approximately RM 60), the study area is located entirely within the FERC Project boundary. Habitats downstream of the boundary were not included in the study because there is significantly increased tributary influence and substantial change in river streambed composition. Nine distinct habitat areas were defined within the study area to assess the potential Project effects on non-fish aquatic resources. The following nine habitats were delineated on the basis of the aquatic conditions including water velocities, water temperatures, substrate composition, and surface fluctuation differences:

1. Transition zones between inlet tributaries and Lake Oroville (TZ)
2. Lake Oroville Reservoir (LOR)
3. Thermalito Diversion Pool (TDP)
4. Thermalito Forebay (TPF)
5. Thermalito Afterbay (TCA)

6. Power Plant/Fish Barrier Reach (PPR)
7. Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet (LFC)
8. Lower Feather River downstream from Thermalito Afterbay Outlet to Honcut Creek (LFR) and
9. Oroville Wildlife Area (OWA) ponds

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

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The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-ft-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-ft-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate an average of 8,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

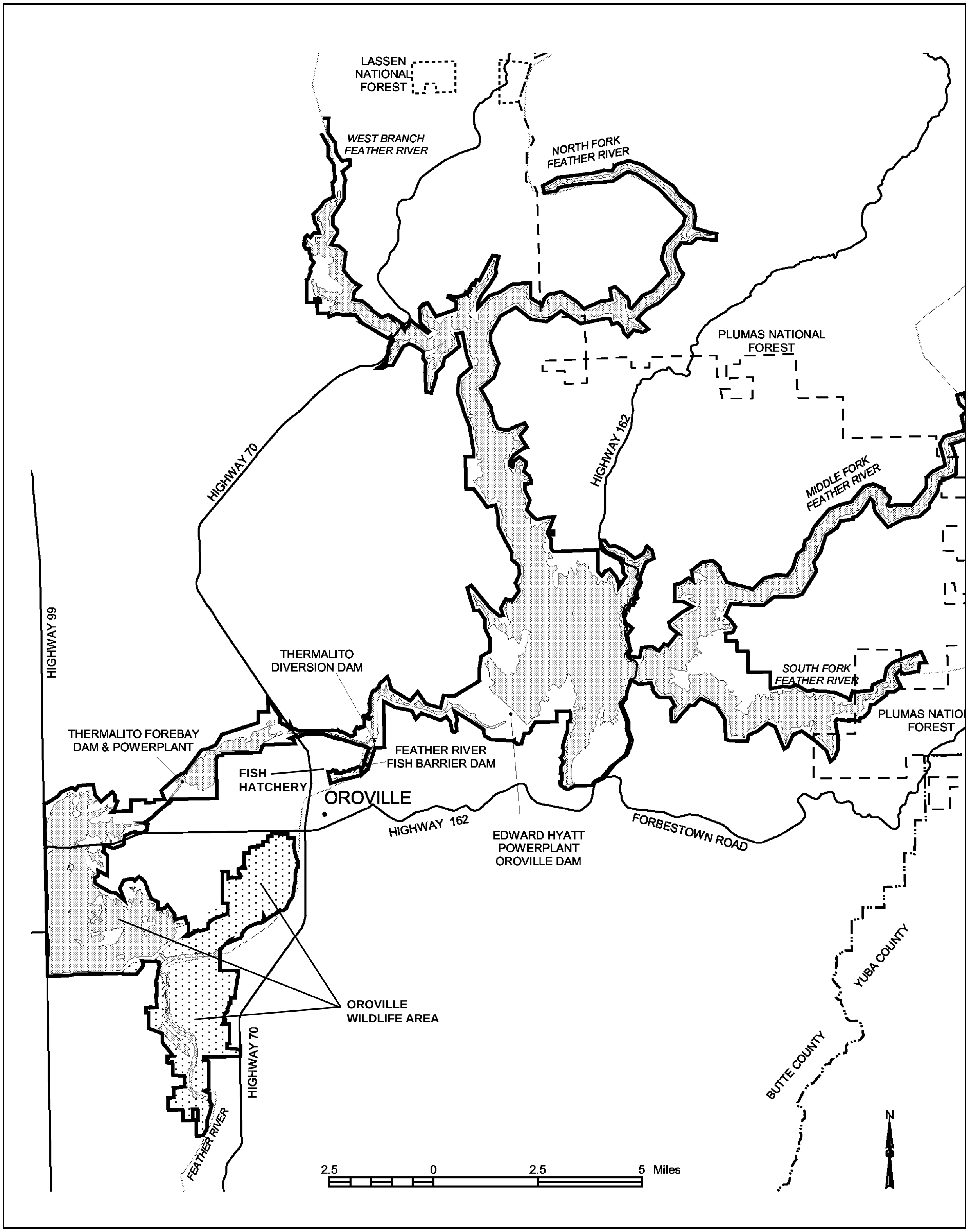

Figure 1.2-1. Oroville Facilities FERC Project Boundary

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for Project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

The purpose of this study was to obtain and review existing information and to qualitatively evaluate the Project's effects on macroinvertebrate and plankton communities. This information is useful for evaluating direct, indirect, and cumulative effects of the Oroville Facilities required to comply with the Federal Energy Regulatory Commission's (FERC) environmental review process under the NUSEPA and ESA consultation information requirements. This study was initiated to collect and compile baseline information on aquatic macroinvertebrate and plankton communities in waters influenced by Project operations in order to evaluate potential Project effects and to provide a foundation for development of future PM&E measures, if needed.
Aquatic macroinvertebrate and plankton communities are related to a variety of environmental factors. The Project has the potential to affect all of these factors in the FERC Project waters. Of significance to biotic communities are potential impacts to water temperature, discharge in the Feather River below Oroville Dam, reservoir fluctuations, and changes to the hydraulic nature of the system.

3.0 STUDY OBJECTIVE(S)

The overall goals of this study were to describe the aquatic macroinvertebrate and plankton resources located within the Project boundary and to evaluate the potential impacts to these resources that result from ongoing Project operations. The study focused specifically on macroinvertebrates and plankton as they are indicators of overall water quality and the prey base for fish. Specific study objectives are listed below.

Objective 1. Describe the aquatic macroinvertebrate, phytoplankton, and zooplankton communities found within Project waters including information on community structure and their habitat conditions.

A review of existing literature, field studies, and Project data was conducted to meet the first objective. The review presented information on operations or environmental conditions that affect plankton and aquatic macroinvertebrate communities within Project waters, as well as information on how aquatic macroinvertebrates and plankton communities have responded to environmental change in other river systems. The review culminated in a description of the current condition of aquatic macroinvertebrate and plankton communities present in both the impounded and free-flowing freshwater habitats within the facility boundaries and the potential effects of future Project operations on this biological resource.

Objective 2. Qualitatively evaluate effects on the aquatic macroinvertebrate and plankton communities that may result from current operations or operational changes at the Oroville facilities.

This analysis has not been completed, but will be available in the final report scheduled for completion in March 2004. Information and data collected to describe non-fish aquatic resources within Project waters will be used to meet the second objective of the study. The lack of long-term field data from Project waters on the abundance and composition of macroinvertebrate and plankton communities will prevent the pursuit of a quantitative or “modeling-based” assessment of Project operations on non-fish resources within the Project boundary. Instead, a five-point categorical scale (strongly positive, positive, neutral, negative, strongly negative) will be used to provide a general assessment of the likelihood of a positive or negative effect from operation of the Oroville facilities. The general effects of physical and chemical alterations from future Project operations on plankton and macroinvertebrate communities will be based on a review of the life history requirements for plankton and macroinvertebrates and scientific judgment.

4.0 METHODOLOGY

4.1 STUDY DESIGN

The primary sources of field data were two recent studies conducted in Project waters. Aquatic macroinvertebrate samples collected by DWR were analyzed to determine the abundance of organisms, number of taxa, taxa guild, and measures of community composition (including several indices). The DFG modification (i.e., California Stream Bioassessment Procedure; (DFG 1999) of the USEPA rapid bioassessment method (USEPA 1989, Barbour et al. 1999) was used to assess aquatic macroinvertebrate communities within the Project area. Within the inundation zone of Lake Oroville, riffle areas in the major tributaries to Lake Oroville were sampled for macroinvertebrates in fall 2002 and will be sampled in the spring 2003 to determine the status of benthic macroinvertebrates and evaluate seasonal changes. In particular, sampling in spring is being conducted to assess whether habitat exposed by reservoir drawdown in the fall is eliminated in the spring due to flooding as the reservoir refills. In the fall when stream discharge is lower, these areas were sampled with a kick screen and metal frame delineating a 2 ft^2 sampling area. Benthic macroinvertebrates will be sampled with an Ekman dredge in the spring when the streambed is inundated by Lake Oroville. At each monitoring station, three transects were established. Three individual samples were collected across each transect and combined, resulting in a combined sample at each transect. Organisms collected were removed from samples using the DFG rapid bioassessment method protocols, identified to the lowest practical taxon, and enumerated.

Aquatic macroinvertebrates also were sampled in four ponds in the Oroville Wildlife Area. Within each pond, ten dredged samples were collected with an Ekman dredge and combined. Organisms were processed using procedures similar to samples collected from the tributaries to Lake Oroville.

A DWR/CSU-Chico collaborative study collected data on benthic and drifting macroinvertebrates at locations in the Feather River upstream and downstream of the Afterbay Outlet. They sampled four locations within the low flow reach of the Feather River and at four locations downstream of the Afterbay Outlet in the lower Feather River, in addition to four locations in side channels adjacent to the sites in the low flow channel (Table 4.1-2). In this dataset, twelve sample sites were established, four in the main river channel of each section (low flow channel: river miles 66.6, 61.9, 61.0, 60.1 and lower reach: river miles 58.5, 55.5, 53.5, 47.2) and four in side channels adjacent to the sites in the low flow channel. All of the samples were collected from riffles. Each site was sampled in January, April, and July of 2002.

Benthic invertebrate samples were collected with a modified Surber samples (1 x 0.5 m, 360 mm mesh, with 0.75 m^2 sampling grid) using an adaptation of the DFG's protocol for rapid bioassessment (DFG Web Site 1999). At each site, three samples were collected (one in the middle and one near each bank) along three randomly chosen transects running perpendicular to the flow. The three samples were collated from each transect into one composite sample and preserved in 90% ethanol. The substrate was disturbed within the sampling grid for ten minutes to standardize collections.

For each transect, the catch was subsampled according to the adaptation of the DFG's rapid bioassessment procedures (DFG 1999). In the lab, each sample was drained of ethanol using a number 30 sieve and the material was laid out in a thin, homogeneous layer on a metal tray divided into 54 grids (4 x 4 cm). All invertebrates were removed with the aid of a dissecting microscope from randomly selected grids until at least 500 individuals were found. Samples from each transect were sorted and identified separately and then averaged together to calculate a site mean.

In 2002, as a component of SP-W1, phytoplankton and zooplankton were sampled from impounded Project waters and the Feather River from 13 locations (Table 4.1-1). Five sites were located in the arms and main body of Lake Oroville, one site upstream of the Lake near Ponderosa Dam, two sites in the diversion pool, four sites in the Thermalito Complex, and one site in the Oroville Wildlife Area ponds.

Phytoplankton and zooplankton were sampled monthly with a plankton net towed from 30 feet in depth to the surface in Lake Oroville and from the bottom in the other impounded areas. Phytoplankton were identified, enumerated, and chlorophyll type was determined. Zooplankton were identified, enumerated, and measured volumetrically.

Further notes on methodology and laboratory analysis will be added during completion of a directional assessment of Project effects on macroinvertebrate and plankton populations in 2003 (Task 2).

Table 4.1-1. List of stations where DWR monitored aquatic macroinvertebrates, phytoplankton, and zooplankton in fall 2002.

General Habitat Area	Habitat Zone	Station Name[1]	Collection Type[2]
Transition zone between inlet tributaries and Lake Oroville	TZ	West Branch	M
	TZ	Concow Creek	M
	TZ	North Fork	M
	TZ	Middle Fork	M
	TZ	South Fork	M
	TZ	Sucker Run	M
	TZ	Ponderosa Dam	P
Lake Oroville	LOR	North Form Arm	P
	LOR	Middle Fork Arm	P
	LOR	South Fork Arm	P
	LOR	Main Body	P
	LOR	Oroville Dam	P
Thermalito Diversion Pool	TDP	u/s from Kelly Ridge	P
	TDP	Thermalito Diversion Pool nr Diversion Dam	P
Thermalito Afterbay	TPA	South Afterbay	P
	TPA	North Afterbay	P
Thermalito Forebay	TPF	South Forebay	P
	TPF	North Afterbay	P
Power Plant/Fish Barrier Reach	PPR	nr Fish Barrier Dam	M
	PPR	Glen Creek	M
Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet	LFC	u/s from Hatchery	M
	LFC	d/s from Hatchery	M
	LFC	d/s from Hwy 162 bridge	M
	LFC	Robinson Riffle	M
Feather River downstream from the Thermalito Afterbay Outlet to Honcut Creek	LFR	d/s from Afterbay Outlet	M
	LFR	d/s from Afterbay Outlet	M
	LFR	d/s from SCOR Outfall	M
	LFR	u/s from Honcut Creek	M
	LFR	Honcut Creek	M
Oroville Wildlife Area Ponds	OWA	Oroville Wildlife Area Ponds	M,P

[1] u/s=upstream; d/s=downstream; nr=near
[2] M=Macroinvertebrates; P=Plankton
Source: Station names from SP-W1 (2002)

Table 4.1-2. List of stations in the Feather River below Oroville Dam where CSU-Chico monitored benthic macroinvertebrates in 2002.

General Habitat Areas	Habitat Zones	Station Name	Collection Frequency
Feather River downstream of Oroville Dam in Project Boundary	LFC	Hatchery Ditch	Jan, Apr, July 2002
	LFC	Hatchery Riffle	Jan, Apr, July 2002
	LFC	Robinson Main	Jan, Apr, July 2002
	LFC	Robinson Side	Jan, Apr, July 2002
	LFC	Steep Main	Jan, Apr, July 2002
	LFC	Steep Side	Jan, Apr, July 2002
	LFC	Eye Main	Jan, Apr, July 2002
	LFC	Eye Side	Jan, Apr, July 2002
Feather River downstream of Oroville Dam outside Project Boundary	LFR	Vance Ave.	Jan, Apr, July 2002
	LFR	Hour	Jan, Apr, July 2002
	LFR	MacFarland	Jan, Apr, July 2002
	LFR	Shallow	Jan, Apr, July 2002

Source: (pers. comm., Boles 2003a)

5.0 STUDY RESULTS

5.1 MACROINVERTEBRATES

DWR collected macroinvertebrate benthic samples from 17 sites within the Study area between September and October 2002. Complete site names associated with DFG site designations used during laboratory analysis are listed in Appendix A-1. Summary data for macroinvertebrates for all DWR sites is presented in Appendix A-2 and A-4. Summary data for Feather River sites used in the DWR/CSU-Chico collaborative study is presented in Appendix A-3.

5.1.1 Entire Study Area

Across the entire Study area (i.e., all sites), the average macroinvertebrate abundance ranged from 1,974 to 16,527 organisms (Table 5.1-1). Samples collected by DWR showed that the overall aquatic macroinvertebrate community was dominated by taxonomic groups such as Chironomidae (true fly, approximately 27%), Baetidae (mayfly, 22%), and Hydropsychidae (caddisfly, approximately 23%) (Appendix A-4). At all sites combined, more than 70% of the macroinvertebrates were composed of these groups. Taxa richness ranged from 14-30, with the highest taxa richness located in tributaries to Lake Oroville upstream of Oroville Dam (Appendix A-2). The percentage of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) taxa varied widely across all sites (5-84%) (Table 5.1-1).

Shannon Diversity Index (SDI) values ranged from 0.8-2.6 throughout the Study area (Table 5.1-1). The index is logarithmic, usually ranges from 1.5-3.5, and reaches its maximum value when all species are distributed evenly (EID 2002). Values were lowest (SDI=0.8) at the site upstream of the Feather River Fish Hatchery and highest upstream of Oroville Dam in the Middle Fork and West Branch portions of the Feather River and in the Fall River (Appendix A-2). Sites in the Feather River below Oroville Dam were relatively uniform with respect to the SDI, with the majority of values ranging from 1.5-2.1 (Table 5.1-1). SDI results obtained to date are consistent with expected values for other large rivers in the Sacramento-San Joaquin watershed (CMARP Benthic Web Site 1998).

Collectors, filterers, and grazers generally were the most dominant functional feeding groups in the Study area. Collectors were dominant in 13 sites, with filterers and grazers dominant at two sites each. Predators and shredders were least prevalent in 13 of 17 sites across the Study area (Appendix A-2). Overall, generalists such as collectors and filterers comprised between 38-97% of the sample across all sites.

Table 5.1-1. Summary information by geographic area for aquatic macroinvertebrates collected by DWR during fall 2002.

Summary Metric Range	Entire Study Area	Upstream Oroville Dam (5 sites)	Downstream Oroville Dam (12 sites)
Mean Taxonomic Richness	14-30	20-30	16-23
% EPT Taxa	5-84	18-68	5-84
Shannon Diveristy Index (SDI)	0.8-2.6	1.9-2.6	0.8-2.3
% Collector	33-91	37-68	33-91
% Filterer	1-51	1-36	4-51
% Grazer	1-47	9-44	0-47
% Predator	1-11	3-11	1-10
% Shredder	0-6	0-6	None found
Avg. Abundance	1,974-16,527	3,146-6,292	1,974-16,527

Source: IEP Database 2003

5.1.2 Area Upstream of Lake Oroville

Upstream of Oroville Dam, macroinvertebrate abundance at sites ranged from 3,146-6,292 organisms (Table 5.1-1). Taxa richness at these sites ranged from 20-30 taxa (Table 5.1-1). The percentage of EPT species varied widely at sites upstream of Oroville Dam. For example, the South Fork Feather River had the lowest percentage (18%) of EPT species while the West Branch (53%) and Middle Forks (68%) of the Feather River had the highest levels of EPT composition (Appendix A-2). SDI values upstream of the dam were fairly uniform, ranging between 1.9-2.6 across all upstream sites (Table 5.1-1). These SDI values generally were higher compared to values at Feather River sites downstream of Oroville Dam, suggesting that upper sites have a more balanced invertebrate community. SDI results obtained to date upstream of the dam are consistent with expected values for other large rivers in the Sacramento-San Joaquin watershed (CMARP Benthic Web Site 1998).

In the North, Middle, and South Forks of the Feather River, the samples were most represented by collectors and filterers (Appendix A-2). In the Fall River, grazers dominated the sample, suggesting that water transparency and algal growth could be high in this reach. Predators and shredders were found infrequently, with these two groups containing less than 16% of the sample across all upstream sites (Appendix A-2). Predators are expected to be found in low numbers in large rivers and shredders usually are not present because there is little course particulate organic matter (Vannote et al. 1980).

5.1.3 Area Downstream of Lake Oroville in Feather River

Macroinvertebrate abundance ranged from 1,974-16,527 at 12 sites in the Feather River (Table 5.1-1). Taxa richness at these sites was highly uniform and ranged from 16 to 23 taxa (Table 5.1-1). Similar to sites upstream of Oroville Dam, the percentage of EPT species varied widely (5-84%) (Table 5.1-1). The site upstream of the Feather River Fish Hatchery had the lowest percentage of EPT species while eight other sites had levels of EPT composition higher than 50% (Appendix A-2). Also similar to upstream locations, SDI values were fairly uniform, ranging between 1.5-2.1 across all sites downstream of the lake (Table 5.1-1). SDI results obtained to date downstream of the dam are consistent with expected values for other large rivers in the Sacramento-San Joaquin watershed (CMARP Benthic Web Site 1998).

Collectors and filterer taxa dominated at all sites in the Feather River (Appendix A-2). These functional groups are expected in the greatest abundance from the high amount of fine particulate organic matter available from upstream processing (CMARP Benthic Web Site 1998). Grazers and predators were less abundant at sites in the Feather River compared to feeding groups such as collectors and filterers. At all sites except Glen Creek, predators accounted for less than 6% of the sample and grazers account for less than 19%. In Glen Creek, grazers dominated the sample (47%), followed in abundance by collectors (35%), and predators (10%). High numbers of grazers in streams suggests that algal growth is high (CMARP Benthic Web Site 1998). Shredders were not found at sites in the Feather River downstream of Lake Oroville and in limited numbers upstream of Oroville Dam. Shredders are usually associated with streams with an intact riparian canopy since these insects feed on accumulations of decomposing coarse particulate organic matter (CPOM) (Vannotte and Sweeney 1980).

Additional downstream populations of benthic macroinvertebrates were sampled in the Feather River by CSU-Chico from river mile 47.2 to 66.6 in winter, spring, and summer 2002 (Appendix A-3). More than 50 taxonomic groups were identified from sampling in this reach. The dominant taxa in this Feather River reach were similar to Feather River sties downstream of Oroville Dam in the DWR study. Samples collected by CSU-Chico showed that the aquatic macroinvertebrate community in the Feather River was dominated by the taxonomic groups of Chironomidae (true fly), Baetidae (mayfly), and Hydropsychidae (caddisfly), Oribatid (water mite), and Simulidae (black fly). For comparision, samples collected by DWR downstream of Oroville Dam showed similar results. The overall aquatic macroinvertebrate community was dominated by the taxonomic groups Chironomidae (true fly), Baetidae (mayfly), and Hydropsychidae (caddisfly) in DWR sampling. The results from CSU-Chico indicate that overall invertebrate densities in the Feather River varied substantially between seasons and supported information on dominant macroinvertebrate taxa from DWR data collections.

5.2 PHYTOPLANKTON

5.2.1 Entire Study Area

Phytoplankton data was collected by DWR from the Lake Oroville and Thermalito Complex (9 sites) in fall 2002 (Appendix B-1). A total of 43 different taxonomic groups were identified from the collected plankton samples. Total counts of phytoplankton ranged from 1 to 642 organisms. In general, total counts of phytoplankton varied among sites and were dominated by the family of Bacillariophyceae (*Aulacoseira granulata* and *Melosira granulata*), followed by Cyanophyceae (mostly *Anabaena* sp. and *Aphanizomenon flos-aquae*). One exception was the sample collected upstream of Lake Oroville at the Middle Fork Feather River that contained the highest number of Euglenophycea (*Phacus* sp.).

Additional study results will be presented in the final report in March 2004 as more data is processed and becomes available from DWR.

6.0 ANALYSES

6.1 LITERATURE AND DATA REVIEW ON NON-FISH AQUATIC RESOURCES

6.1.1 Aquatic Macroinvertebrates

Prior to construction of Oroville Dam, the Feather River was free-flowing and invertebrate groups had adapted over time to riverine habitat. Under natural hydrologic cycles, water was high in the winter and spring and lower in the summer and fall. Natural floods flushed sediment downstream and created interstitial spaces in stream substrates that provided habitat for some stream invertebrates. Erman (1996) writes that change arrived with the construction of dams, diversions, roads, and other barriers, "there is no, or almost no, similarity between invertebrate assemblages in running water and those in standing water". Major taxa of many invertebrate groups can be found in both free-flowing and impounded waters, but species composition usually is different.

California has not systematically surveyed aquatic habitats statewide for aquatic invertebrates (Erman 1996). Current descriptions of macroinvertebrate diversity in California estimated taxa richness on a regional scale, thus they are limited in their completeness (Table 6.1-1).

Table 6.1-1. Species estimates of selected aquatic invertebrate taxa in California and the Sierra Nevada region.

Taxon	Total in California	Total in Sierra Nevada	Number Endemic to Sierra Nevada	Percentage Endemic to Sierra Nevada
Stoneflies (Plectoptera)	167	122	31	25
Alderflies (Megaloptera)	6	4	0	0
Dobsonflies (Megaloptera)	11	7	?	?
Caddisflies (Trichoptera)	308	199	37	19
Net-winged midges (Diptera)	16	11	1	9
Mountain midges (Diptera)	6	4	1	25
Snails, clams (Mollusca)	?	40	8	20
Fairy shrimp, brine shrimp (Anostraca)	23	10	1	10

Source: Erman 1996

6.1.1.1 Measures of Biotic Health for Macroinvertebrates

Invertebrates have been used widely as an indicator to assess stream and reservoir health. A variety of techniques have been used to assess macroinvertebrate communities. Many current invertebrate assessments in California are conducted according to modifications of the USEPA protocol. Stream health is usually determined by the species diversity of the assemblage present or through groupings at higher taxonomic levels. Negative impacts resulting from environmental shifts or anthropogenic impacts are shown by decreasing species diversity, organism size, or changes in taxa composition (Erman 1996).

Multimetric indices have been used for assessing the biological integrity of macroinvertebrate communities in lotic systems because they integrate, condense, and summarize biological data, thus allowing laypersons to understand overall environmental conditions (Barbour et al. 1995, Resh and Jackson 1993, Simon and Lyons 1995). Multimetric indices have been widely used for rivers (Ohio USEPA 1987, DeShon 1995, Barbour et al. 1999, Plafkin et al. 1989), and less often utilized in lakes (Stueben et al. 2001) to assess ecosystem health. Components of these indices include data classification into formats that show taxa richness, relative abundance, tolerance measures, and feeding measures. These metrics are described in further detail below.

Taxa richness, or the number of distinct taxa, represents the diversity within the aquatic assemblage (Resh et al. 1995). Richness measures have been evaluated at the species level or in designated groupings of taxa, often as higher taxonomic groups. Increasing diversity generally correlates with increasing health of the assemblage and suggest that niche space, habitat, and food sources are adequate to support survival (Barbour et al. 1999). Taxa richness is the key element in indices such as the Invertebrate Community Index (ICI) (DeShon 1995), fish Index of Biotic Integrity (IBI) (Karr et al. 1986), and benthic Index of Bitotic Integrity (IBI) (Kerans et al. 1992, Kerans and Karr 1994), and is used in Rapid Bioassessment Protocols (RBP) (Plafkin et al. 1989).

The relative abundance of taxonomic groups within an assemblage has given insight into the status of aquatic invertebrate populations and the ecological patterns that act on them. Healthy and stable aquatic invertebrate assemblages should be relatively consistent in their proportional composition (Barbour et al. 1999). Measures of composition have been useful when evaluating the impacts from nuisance or exotic species or for understanding the interaction among taxonomic groups.

Tolerance measures have been applied to better understand the level of perturbation on aquatic invertebrate assemblages, usually from pollution or habitat degradation (Barbour et al. 1999). Metrics such as the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987, 1988) and Biotic Condition Index (Winget and Mangum 1979) have been used to detect problems with organic pollution and sedimentation, respectively. Tolerance measures may be independent of taxonomy or applied to specific taxa groups.

Feeding measures consist of functional feeding groups and provide information on feeding strategies in the aquatic invertebrate population (Barbour et al. 1999). The most common type of feeding measure involves separating sampled organisms into feeding orientations of scrapers, shredders, gatherers, filterers, and predators. Stable stream and reservoir ecological systems reflect a diversity of feeding orientations and usually contain specialized feeders (e.g., scrapers, shredders, and piercers). An imbalance of generalists (e.g., collectors and filterers) compared to specialized feeders usually reflects disturbed conditions because generalists are less susceptible to pollution and habitat alteration (Barbour et al. 1999). Segregation of sampled organisms by feeding orientations is difficult because proper assignment to functional feeding groups is necessary, a process that can be difficult, costly, and time consuming. Thus, the usefulness of these measures has been contested in many studies (Erman 1996, Barbour et al. 1999).

Although rapid assessment approaches are usually cost effective and provide an understandable result to a diverse audience, limitations can reduce their effectiveness. One major disadvantage to most monitoring studies is their lack of sample replication (i.e., documentation of long-term environmental variability) (Rosenburg and Resh 1996). Other disadvantages are that taxa are generally not identified to species and random assignment of taxa (usually genera or family) to functional feeding groups can occur (Erman 1996).

6.1.1.2 General Effects of Dams and Barriers on Macroinvertebrate Communities

Altered flow regimes can have significant impacts on macroinvertebrate communities. Flow regulation can result in decreased magnitude of temperature fluctuations compared with natural conditions, interruptions in the cycling of nutrients, food, and sediment, and alterations in the geomorphological characteristics of the river (BioWest, Inc. 2002). Altered flow regulation also can change seasonal temperature regimes in the rivers below dams by providing cooler temperature water in the summer and warmer temperature water in the winter. Changes in the seasonal timing of the flow and temperature regimes can impact life history characteristics of individual aquatic species, which in turn affects the composition of communities. Adverse impacts to invertebrate and plankton communities usually result in a decrease in organism size and a decrease in diversity, depending on the degree of impact (Erman 1996). In many cases, altered tailwater habitats may favor a select number of species (especially Baetis), resulting in a community where high numbers of fewer species are present. Dipteran and worm populations generally increase in abundance in tailwater release areas, while mayfly, stonefly, and diversity in other benthic orders can be significantly reduced (BioWest, Inc. 2002). Information is summarized below for two river systems affected by altered flow regimes to provide examples of the potential impacts of such changes on macroinvertebrate communities.

<u>Green River below Flaming Gorge:</u> In the Green River, a principal tributary to the Colorado River, Flaming Gorge Dam has dampened the natural hydrograph and impacted the natural temperature regime (Vinson 2001). The pre-dam community had densities that were relatively low at about 1,000/m^2, and 60-80% of the community was comprised of mayfly taxa. After dam construction, overall macroinvertebrate densities increased and there was a resulting decrease in macroinvertebrate diversity. Midges

and blackflies dominated the community and mayfly taxa were severely reduced after modification of the natural hydrograph. Vinson (2001) determined that the warmer winter and cooler summer water temperatures resulting from the dam operation played a role in reducing diversity. Vinson also noted that high densities of some species in the post-dam environment prevented some species from recolonizing the area below the dam and that the dam limited downstream drift.

San Juan River below Navajo: In the San Juan River below Navajo Reservoir (UT), similar alterations in the temperature regime of the river below the dam impacted benthic communities. Holden et al. (1980) noted that sampling locations closest to the dam contained the highest macroinvertebrate densities and the lowest diversity. Mayflies, caddisflies, and stoneflies were poorly represented in the 13 miles of stream downstream of the dam, but increased in abundance at stations further downstream in the San Juan River. The communities at the base of the dam were dominated by midges, blackflies, and worms (Dubey 1996).

These two case studies suggest that prolonged temperature and flow alterations in the Feather River below Oroville Dam likely impacted macroinvertebrate communities. Warmer winter temperatures and colder summer water resulting from regulated discharge likely has affected individual species' life cycles and decreased overall species diversity near the dam. Lemly (1982) notes that the presence of different functional feeding groups (i.e., diversity) in ecosystems allows allochthonous and autothonous inputs to be processed and made available to higher trophic levels. Any potential disturbance with detrimental effects to water quality and stream invertebrate populations will be reflected in the fish population as well (Lemly 1982).

6.1.1.3 Effects of Ramping Rates on Macroinvertebrate Communities

Discharge changes resulting from hydroelectric peaking directly affects water levels, water temperatures, and velocities and can alter benthos and fish abundance and distribution (Brusven and MacPhee 1976). Fluctuating water levels from dams also can stimulate invertebrate drift downstream (Minshall and Winger 1968, Brusven and Trihey 1978, Bovee 1985) or strand invertebrates as water levels are lowered suddenly and stream channels dry up (Erman 1996). Stranding of benthic insects during rapid drawdown have been shown to cause detrimental effects at higher trophic levels (Kroger 1972). For example, extreme reductions in flow in the tailwater of Dworshak Dam on the Clearwater River, Idaho significantly increased the amount of insect drift and the rate of ingestion by salmon in the diversion channel (Brusven and MacPhee 1976). In addition, downstream shorelines experiencing daily fluctuations from dam releases were not readily colonized by stoneflies, mayflies, and caddisflies; chironomid midges were the most resilient stranded insects in these unstable areas and the first ones to recolonize the flooded areas (Brusven and MacPhee 1976).

In other relicensing efforts, macroinvertebrate communities have been evaluated by focusing on relationships between the occurrences and densities of macroinvertebrates and abiotic factors such as water depth, velocity, and substrate composition. Hydraulic analysis and habitat suitability functions have been developed from these data to evaluate the amount of habitat available for macroinvertebrates under existing and alternative scenarios (Harza Engineering Company 1987). In this same study, relative abundance of taxa in smallmouth bass stomachs were compared with relative abundance in benthic samples to determine the direct dependence of smallmouth bass populations on riffle-area macroinvertebrates (Harza Engineering Company 1987). Ongoing research related to the Oroville Facilities Relicensing is providing similar information for fish species in the Project area. In addition to these ongoing feeding studies, ongoing IFIM studies are being conducted to assess the amount of fish habitat under various flow scenarios. Habitat variables used in the IFIM analysis can be used to evaluate the amount of available habitat for benthic macroinvertebrates under various flow regimes, as well as incorporate habitat preferences of macroinvertebrates from the literature. Potential impacts to macroinvertebrate and plankton populations from changes in water quality and other factors associated with altered Project operations also will be assessed.

6.1.1.4 Patterns of Macroinvertebrate Migration and Recolonization

The aquatic stages of most stream insects involve short migration distances (< 300 m). These migrations are important ecologically as a means for genetic dispersal and the insects' stream-colonization cycle (Vaughan 2002). Migrations can occur along the substrate or via drift. Migrating invertebrates that are competitively inferior in one patch can avoid competition and access preferred habitats by moving to new habitat. Drift has been shown to be an important dispersal mechanism for many macroinvertebrates (Benson and Pearson 1987). Not surprisingly, increased macroinvertebrate drift can be correlated with higher stream flows (Williams and Williams 1993), although in some systems, extreme reductions in discharge below hydropower projects have stimulated insect drift (Brusven and MacPhee 1976). Drift also can be associated with diel periods. In the Clearwater River, Idaho, numbers of drifting insects were greatest at night (Brusven and Trihey 1978). In summary, macroinvertebrate drift is characteristic of populations in running water and is plays an important ecological role by providing a mechanism for recolonization of disturbed areas and by providing increased food for predators (Merrit and Cummins 1996).

In addition to drift, aquatic invertebrates have evolved several methods to recolonize disturbed areas, including swimming, crawling, and flight (MacKay 1992). Most aquatic insects are able to fly upstream during their adult phase, but large barriers such as large waterfalls and dams prevent migration along the stream corridor for most species. Surface barriers may also be associated with degraded water quality and also may concentrate predators (Vaughn 2002). In addition, several studies have documented shifts in the relative contribution of functional feeding groups associated with small stream barriers (e.g., culverts) (King et al. 2000, Vaughan 2002).

Recolonization experiments in lotic systems have supported the contention that streams are patchy environments. Abiotic factors such as season, water temperature, substrate, and discharge were important in colonization and thus determine the structure of the benthic community (Moser and Minshall 1996). In a third order Rocky Mountain stream in Idaho, colonization of the benthic community through drift was important in spring when water temperature and algal resources were low and discharge was high (Moser and Minshall 1996). In summer and fall, when water temperatures were high, discharge was low, and algal resources were abundant, drifting and crawling taxa colonized equally rapidly (Moser and Minshall 1996), suggesting that certain modes of colonization can vary in importance on a seasonal basis and can depend on the ambient environment. In this experiment, drifting invertebrates that were competitively inferior in one patch during spring could avoid competition and access alternative habitats by moving to areas less accessible to some members of the assemblage (Moser and Minshall 1996). Potential impacts to seasonal patterns of macroinvertebrate recolonization could result from changes in Project operations that alter water temperatures and discharge.

6.1.1.5 Effects of Fish on Macroinvertebrate Communities

Fish predation does not appear to control macroinvertebrate communities in all streams, although many studies have shown that fish do alter aspects of macroinvertebrate communities in some cases. Experimental removal of trout in Rocky Mountain streams showed that macroinvertebrate densities were not significantly different between natural and predator removal streams (Allan 1982). Power (1990) showed that predatory fish in the Eel River, California, affected predatory invertebrates, which in turn controlled the abundance of larval chironomids. In many of the reported field experiments relating to fish predation and macroinvertebrates, fish impacted communities by their size-specific feeding habitats, typically resulting in the depletion of larger individuals from the population and subsequent effect on community composition and numbers (Helfman et al. 1997).

6.1.2 Water Quality Effects on Macroinvertebrates

6.1.2.1 Effects of Sediment on Macroinvertebrate Communities

Suspended sediment can interfere with the reproductive, respiratory, or feeding behavior of surface-oriented macroinvertebrates. Sediment may also interfere with drifting behavior via abrasion or elevated turbidity. Increased sediment can decrease available habitat for benthic macroinvertebrates by creating highly embedded stream substrates with no pore spaces available for invertebrate colonization (Erman 1996), as well as preventing clinger-type organisms from clinging to rock substrates. Suspended particles also are an important component of nutrient and energy cycling and transport in lotic systems (Whiles and Dodds 2002). Generally, as sediment increases, species richness, density, and biomass decrease (Johnson et al. 1993).

Studies on the direct effects of suspended or deposited sediment on macroinvertebrates indicate that the most common ones are abrasive action, loss of visual efficiency in feeding, and interference in food gathering by filter-feeding insects (e.g., net-spinning caddisfly larvae), or an decrease in abundance, biomass, survival, and productivity. Many sediment invertebrate studies are associated with gravel dredging or mining operations. In general, these studies show decreases in abundance or biomass (Cordone and Kelley 1961, Forsage and Carter 1974, LaPerriere et al. 1983, Wagener and LaPerriere 1985) or altered feeding (Aldridge et al. 1987) as a result of increased suspended sediment levels in rivers. Brunskill et al. (1973) reported reductions in filter feeders as suspended sediment concentrations in the Mackenzie River, Canada became elevated. Indirect effects of sediment on macroninvertebrates include increases in invertebrate drift, presumably as a consequence of reduced light, and the adverse effects associated with the redeposition of sediment at high levels (Waters 1995).

Turbidity has been hypothesized to be a factor affecting macroinvertebrate movement and distribution. In southwestern North Carolina, turbidity, suspended load, and bed load were found to have significant effects on species richness and diversity in the insect community (Lemly 1982). Chironomids were found in high numbers in the zones receiving sedimentation (Lemly 1982). Taxa that were most affected by increased sedimentation were the filter feeding Trichoptera and Diptera. Predaceous Plectoptera and some Ephemeroptera taxa also showed decreased abundance and diversity associated with increased sediment levels and turbidity (Lemly 1982). Lemly (1982) notes that studies attempting to measure correlations between turbidity and macroinvertebrate drift often were confounded by unregulated light levels during the experiment (Doeg and Milledge 1991, Rosenberg and Wiens 1978, 1980); light is known to influence invertebrate movement. At least one study indicated that there was not a correlation with sediment and drift (O'Hop and Wallace 1993).

6.1.2.2 Effects of Temperature on Macroinvertebrate Communities

The ambient thermal environment affects the life history, development, and distribution of aquatic macroinvertebrates (Vannote and Sweeney 1980). Metabolism, growth, emergence, and reproduction are directly linked to water temperature whereas food availability may be indirectly linked with temperature regimes (Merrit and Cummins 1996). In shallow lakes or along shorelines, higher water temperatures can result in greater algal food supply and faster growth, but during summer these areas may be oxygen limited. Alteration of thermal regimes outside the optimal range for individual species can affect fitness by decreasing body size and fecundity (Merrit and Cummins 1996).

Invertebrate communities have been shown to be affected by the modified temperature releases below hydroelectric facilities or by thermal pollution. These effects include, but are not limited to: (1) reduction of niche overlap and a shift toward an equilibrium community as a consequence of reduced environmental fluctuations; (2) more intense competition associated with greater productivity; (3) elimination of major invertebrate predators; and (4) failure of the limited temperature range to provide optimal temperatures for various physiological processes (Ward 1976). In a more general sense, altered regions below dams or in areas with thermal pollution with characteristic higher winter water temperatures and lower summer temperatures can fail to provide the thermal cues critical for life-cycle phenomena (Coutant 1968, Pearson, Kramer, and Franklin 1968, Nebeker 1971, and Lehmkullh 1972, 1974). The relatively constant environmental conditions found in streams below deep-release dams may cause shifts toward a community marked by equilibrium, or could be generally disadvantageous (Hubbs 1972). In a study on thermal pollution, Wellborn and Robinson (1996) reported there was no evidence to show that thermal effluents enhanced densities of macroinvertebrates during the winter, but effluents contributed to thermal stress of aquatic organisms during summer in Fairfield Reservoir, Texas.

The composition of invertebrate communities below dams is dependent on patterns of emergence, which are highly affected by water temperature. One effect of water temperature on emergence is accelerated growth rates and premature emergence. An example of this is provided by Coutant (1968), who showed that a 1°C increase in water temperature caused Hydropsychidae to emerge two weeks earlier in the Columbia River. In general, invertebrate species that do not require low water temperatures for hatching may be eliminated below dams if their growth rate is accelerated in the winter or decreased in the summer and premature emergence occurs. Invertebrates that emerge prematurely may encounter air temperatures lethal to aerial adults or experience decreases in productivity from inactivated mating mechanisms or because of nonsynchronous emergence of males or females (Ward 1976). Water temperature also may cause shifts in community structure by having detrimental impacts on the physiological requirements of certain species within the macroinvertebrate community. For example, the necessity of near freezing followed by higher temperatures to stimulate hatching may explain the absence of some mayflies below dams (Lehmkuhl 1972). In warm conditions, constant water temperatures may cause extended emergence for some species (Ward 1976). The ecological consequence of extended emergence for a species can be niche overlap, altered productivity, or increased life-cycle diversity.

6.1.3 Phytoplankton and Zooplankton

6.1.3.1 Effects of Dams on Phytoplankton and Zooplankton Communities

Phytoplankton and zooplankton are important sources of energy for stream and reservoir ecosystems. The abundance and distribution of these organisms in rivers and reservoirs are highly dynamic and are most affected by light, nutrients, temperature, flow, and presence of herbivores (Murphy 1998). These organisms vary widely in function and size, and are subject to large spatial and temporal variations in diversity and abundance (Wetzel 2001). In eutrophic and alkaline lakes and reservoirs, diatoms are commonly dominant during much of the year, with green algae and cyanobacteria commonly occurring during warmer periods (Hutchinson 1967). In highly eutrophic systems or during warm periods, cyanobacteria commonly dominate the plankton community, with the presence of euglenoids if the water body is organically enriched or polluted (Hutchinson 1967). A summary of specific potential effects on plankton communities associated with light, sediment, fish, water temperature, and nutrients is contained in the following sections.

6.1.3.2 Effects of Light on Phytoplankton and Zooplankton

One of the most important factors that limits primary production is light (Murphy 1998). Phytoplankton and algae exhibit increased photosynthesis up to the level of light saturation. When light levels are higher than saturation, other limiting factors, such as nutrients and water temperature, impact their abundance. Habitats where light saturation may occur are along the surface of reservoirs, or in streams and ponds with limited shading from riparian vegetation. Light intensity has been shown to affect both the rate of photosynthesis and algal growth (Wetzel 2001). A considerable degree of adaptation can occur with changing light intensities and responses to light intensities are species-specific in many instances (Wetzel 2001).

6.1.3.3 Effects of Sediment on Phytoplankton and Zooplankton

Increased levels of suspended sediment can decrease water transparency and reduce photosynthesis (Waters 1995). Sediment also can abrade or suffocate periphyton and macrophytes (Waters 1995). Negative correlations between turbidity and primary production in rivers have been shown in several studies (LaPerriere et al. 1983, Pain 1987), but there is limited empirical evidence that shows stream communities are damaged through reduced photosynthetic rates (Waters 1995). Organic matter from sediments also has been shown to provide seasonal inputs of nutrients into the system which can subsequently cause seasonal variations in phytoplankton blooms (Cloern et al. 1983). The effects of turbidity are often difficult to distinguish from other environmental variables that may affect rates of primary production, such as water temperature and nutrient concentrations.

Turbidity in reservoirs from clays and silt may also suppress zooplankton growth and productivity by direct interference mechanisms (Wetzel 2001). In the taxa cladocera, mechanical interference of suspended clay particles reduced feeding rates and suppressed growth and reproduction (Kirk 1992). Suspended clay also suppressed growth and reproduction of ciliates, but had minimal effects on other plankton groups (Hart 1986, Jack and Gilbert 1993). Turbidity in reservoirs also may affect the community structure of zooplankton (Kirk and Gilbert 1990, Kirk 1991, Cuker and Hudson 1992). Zooplankton that feed on clay particles have been found to improve water clarity, although interactions between feeding rates and algal growth make causative links difficult (Gliwicz 1986, Wetzel 2001). Filter-feeding zooplankton species can be negatively affected during flooding events, as algal resources are small in proportion to more abundant silt particles (Kirk 1992).

6.1.3.4 Effects of Fish on Phytoplankton and Zooplankton Communities

Fish can impact the trophic structure of reservoirs and rivers. In addition to their important role in nutrient cycling, planktivorous fish have been shown to feed selectively on larger zooplankton, effectively causing a shift in community structure toward smaller-sized zooplankton (Helfman et al. 1997). Planktivorous fish also have been shown to affect the diel vertical migrations of zooplankton, their age at sexual maturity, and the average size of offspring (Helfman et al. 1997). Shifts in zooplankton community structure can, in turn, influence phytoplankton species composition and primary production (Scheffer et al. 2000). Conceptual mechanisms that have been proposed to explain this complex trophic interrelationship include the trophic cascade (Paine 1980) and biomanipulation (Shapiro et al. 1975, McQueen 1990). There is a high level of scientific support to suggest that phytoplankton composition and abundance is influenced by zooplankton and fisheries assemblages, although the exact nature of these effects is often dampened by confounding environmental variables (Reynolds 1999).

Fish generally crop no more than 5-10% of zooplankton production annually, although more severe impacts have been observed (Helfman, Collette, and Facey 1997). For example, alewives and yellow perch consumed 97% of the zooplankton in Lake Michigan in 1984 (Evans 1986). Compared to lake productivity and water quality, however, fish predation intensity must be very high to become the main determinant of the zooplankton community (Vanni et al. 1990, Hessen et al 1995).

Lake Oroville contains many species of herbivorous fish and other fishes that may use this feeding strategy under resource limitation. Species with herbivorous feeding strategies have the most potential to impact zooplankton and phytoplankton assemblages in Project waters. In general, fish production in reservoirs is highly variable and species-specific. For example, salmonids have been shown to have annual production rates of 0.21-66 kg/hayr from standing waters (Bisson and Bilby 2001). In comparison, annual production estimates of cyprinids (minnows and carp) have been documented as high as 1000 kg/hayr, at least an order of magnitude higher than salmonids (Bisson and Bilby 2001). Although the specific trophic dynamics in Lake Oroville have not be documented, it is clear that the degree of impact from fishes to plankton populations in Lake Oroville and other Project waters is dependent on a suite of factors, including water quality, habitat characteristics, and the dynamics of the biotic asssemblage present during the year.

In 1990, McQueen reviewed later reservoir manipulation studies to identify trends in fish/plankton interactions. This review found that effects on plankton communities by fish are seen more often in shallow lakes or in situations where fish communities are strongly manipulated. Plankton dynamics in deep lakes are controlled more by water quality and other factors than by fish manipulation (McQueen 1990). The maximum depth of Lake Oroville is approximately 722 ft and thus likely falls into a category of reservoirs with plankton communities that are controlled by water quality. McQueen (1990) also noted that there was a no predictable evidence for fish/plankton interactions.

6.1.3.5 Effects of Water Temperature on Phytoplankton and Zooplankton Communities

Reservoir populations of phytoplankton provide an important source for downstream populations in downstream reaches (Lieberman et al. 2001). Temperature control devices and their effect on particulate organic matter and plankton downstream of Shasta Dam were investigated recently in the Sacramento River, California (Lieberman et al. 2001). Downstream of Shasta Dam, epilimnetic withdrawals from January to mid-June, and mid-level withdrawals through August resulted in localized increases in small particulate organic matter at Shasta tailwaters and increases in phyto- and zooplankton biomass, as well as an increase in biotic diversity. This is consistent with research that shows tailwaters usually contain a high density of lentic phytoplankton and zooplankton that decreases rapidly with distance from the outfalls (Hynes 1970, Novotny and Hoyt 1982). Ward and Wetzel (1975) observed that dams which release water from the hypolimnion typically have smaller impacts to downstream communities compared with dams which release water from the epilimnion. Lieberman et al. (2001) note that these changes potentially affect the food base of the Sacramento River and therefore could affect threatened and endangered species or specific races of Chinook salmon.

6.1.3.6 Effects of Nutrients on Phytoplankton and Zooplankton Communities

Phytoplankton and zooplankton communities in reservoirs and rivers are affected by the nutrient content of the water in particular the nitrogen (N) and phosphorus (P) loading.

The literature suggests that both elements can limit or increase aquatic primary production, depending on the ratio of the two elements present in the ecosystem. The mechanisms governing the nutrient/biotic interaction are unclear (Reynolds 2001). However, P often will be the first nutrient to become limiting because it is usually less abundant than N (Wetzel 2001). Numerous laboratory (O'Brien and DeNoyelles, Jr. 1974, Currie and Kalff 1984) and field studies (Dillon and Rigler 1974, Patterson et al. 1996) have investigated the N:P and other chemical relationship in lakes and its impact to phytoplankton and zooplankton species; many of these cited studies, as well as other field and laboratory studies are reviewed or cited in Wetzel 2001 and Murphy 1998. Nutrient loading in stream and reservoir systems commonly arise when nutrient rich, point-source effluents are added to waters, such as from nearby agricultural operations. In addition to increases in primary production, nutrient rich effluents have been shown to affect the size of plankton. For example, after additions of effluent to an agricultural area in Israel, plankton assemblages were dominated by larger species without a corresponding change in total abundance (Teltsch et al. 1992).

Other nutrients such as carbon and silica have been shown to limit aquatic primary production. In streams, carbon is usually found in sufficient quantities because of water turbulence and high carbon dioxide solubility (Wetzel 2001). Silica is a required material for diatoms, but not for most other algae (Werner 1977). Spring blooms of diatoms in rivers and reservoirs may deplete available silica, leading to shifting community structure dominated by species that do not require silica for cell division (Murphy 1998, Wetzel 2001).

It's clear that nutrient composition is important for determining assemblage structure in plankton, but many studies have documented the difficulty in explaining population responses directly with nutrient concentrations. Reynolds (1998) points out that the ecological factors that drive changes in plankton abundance and composition are varied, complex, and are not fully understood. Modeling approaches have been useful in researching the community ecology of plankton, but are difficult to predict biomass growth because of confounding environmental factors. These models have inputs of plankton functional groups, swimming and settling rates, grazing rates, and nutrient and light inputs (Reynolds 1999, Reynolds et al. 2001).

In lakes, phytoplankton communities typically exhibit regular annual periodicity as a result of seasonal changes in nutrient concentrations (Barbiero et al. 1999). As the year progresses, competition for increasingly scarce nutrient supplies results in changes to the community composition (Barbiero et al. 1999). Disturbances, such as wind or storms, typically permit some species to recolonize habitats and may lead to temporary increases in species richness as representatives of earlier and later successional stages respond to environmental change (Barbiero et al. 1999). For zooplankton, lake productivity has been shown to affect species distribution in rivers and lakes (Wetzel 2001). Field surveys of Florida lakes have indicated that zooplankton abundance is significantly higher in eutrophic systems compared to oligotrophic systems (Blancher

1984). Eutrophic systems were dominated by rotifers and often experienced highly variable fluctuations in abundance (Blancher 1984). Oligotrophic systems were dominated by copepods and populations were more stable (Blancher 1984).

6.2 PROJECT RELATED EFFECTS

This directional analysis has not been completed but will be available in March 2004.

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APPENDIX A—MACROINVERTEBRATE RAW DATA

Table A-1. Full macroinvertebrate and plankton sampling station names associated with DFG site designations used during laboratory analysis.

Station Name	DFG Designation
Upstream of Lake Oroville	
Fall R. US Feather Falls	FR-AFF
Feather R MF nr Merrimac	FRMF-NM
Feather R NF US POE PH	FRNF-PPH
Feather R SF ab Ponderosa Res.	FRSF-APR
West Branch nr Paradise	WBFR-NP
Downstream of Lake Oroville	
Feather R A Robinson Riffle	FR-RR
Feather R A Shanghai Bend Falls	FR-ASBF
Feather R DS Afterbay Outlet	FR-A0
Feather R DS Hatchery	FR-DSH
Feather R DS Hwy 162	FR-H162
Feather R DS Project Boundary	FR-BPB
Feather R DS SCOR Outfall	FR-BSO
Feather R nr Mile Long Pond	FR-NMLP
Feather R US Afterbay Outlet	FR-AAO
Feather R US Archer Ave.	FR-AAA
Feather R US Hatchery	FR-USH
Glen Creek	GC-1

Source: (pers.comm., Boles 2003b)

Table A-2. Summary metrics for aquatic macroinvertebrates collected by DWR during 2002.

Site Name:	Fall River		Feather River Middle Fork		Feather River North Fork		Feather River South Fork		Feather River West Branch	
CDFG Site Code:	FR-AFF		FRMF-NM		FRNF-PPH		FRSF-APR		WBFR-NP	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Taxonomic Richness	29	0.02	30	0.10	20	0.25	28	0.16	30	0.05
Cumulative Taxa	45		44		37		38		45	
Percent Dominant Taxon	22	0.10	26	0.17	42	0.43	54	0.13	26	0.27
EPT Taxa	14	0.04	18	0.11	10	0.06	7	0.21	15	0.08
EPT Index (%)	42	0.20	68	0.08	39	0.42	18	0.16	53	0.18
Sensitive EPT Index (%)	34	0.16	11	0.47	1	0.87	0	1.01	21	0.22
Cumulative EPT Taxa	22		28		15		12		28	
Shannon Diversity	2.6	0.01	2.5	0.10	1.9	0.17	2.0	0.15	2.6	0.07
Tolerance Value	3.1	0.08	4.3	0.09	5.4	0.03	5.6	0.03	4.0	0.06
Percent Intolerant Taxa (0-2)	34	0.14	11	0.43	1	1.29	2	1.24	19	0.36
Percent Tolerant Taxa (8-10)	0	-	1	0.67	1	0.55	2	0.75	2	0.72
Percent Chironomidae	18	0.32	9	0.75	28	0.88	54	0.13	26	0.27
Percent Collectors	37	0.08	51	0.26	51	0.48	68	0.05	52	0.15
Percent Filterers	1	1.73	34	0.50	36	0.99	15	0.34	17	0.58
Percent Grazers	44	0.10	10	0.32	11	0.73	9	0.49	23	0.13
Percent Predators	11	0.44	4	0.44	3	1.39	8	0.06	7	0.22
Percent Shredders	6	0.42	1	1.18	0	-	0	-	1	0.94
Average Abundance (#/ sample)	3,146	-	6,292	-	3,580	-	3,435	-	3,834	-

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected by DWR during 2002.

Site Name:	Feather River											
CDFG Site Code:	FR-AAA		FR-AAO		FR-AO		FR-ASBF		FR-BPB		FR-BSO	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Taxonomic Richness	16	0.13	19	0.18	17	0.19	16	0.06	17	0.16	16	0.10
Cumulative Taxa	23		31		25		21		21		23	
Percent Dominant Taxon	54	0.25	32	0.47	43	0.16	31	0.17	40	0.16	42	0.16
EPT Taxa	9	0.07	6	0.18	10	0.20	7	0.08	11	0.24	8	0.13
EPT Index (%)	68	0.08	55	0.26	76	0.10	72	0.25	84	0.09	68	0.13
Sensitive EPT Index (%)	2	0.57	0	1.00	1	0.57	3	0.36	2	0.48	0	1.18
Cumulative EPT Taxa	12		10		12		9		14		12	
Shannon Diversity	1.5	0.19	2.0	0.17	1.9	0.11	1.9	0.17	1.8	0.05	1.8	0.03
Tolerance Value	4.7	0.03	5.2	0.07	4.6	0.02	4.7	0.09	4.5	0.04	4.7	0.03
Percent Intolerant Taxa (0-2)	2	0.57	0	0.87	1	0.59	3	0.34	2	0.34	0	1.18
Percent Tolerant Taxa (8-10)	3	0.66	8	0.72	0	1.14	1	1.16	0	0.40	1	0.54
Percent Chironomidae	24	0.28	15	0.21	10	0.13	18	0.76	8	0.39	18	0.38
Percent Collectors	88	0.05	49	0.33	33	0.16	68	0.11	61	0.09	35	0.26
Percent Filterers	4	0.66	40	0.51	51	0.11	20	0.66	30	0.52	46	0.19
Percent Grazers	6	0.21	8	0.38	15	0.61	6	1.27	8	1.14	17	0.31
Percent Predators	2	0.86	3	0.67	2	1.01	5	0.64	1	1.22	2	0.60
Percent Shredders	0	-	0	1.73	0	-	0	-	0	1.73	0	-
Average Abundance (#/ sample)	1,974	-	5,084	-	4,286	-	5,638	-	5,041	-	4,992	-

Table A-2 (continued). Summary metrics for aquatic macroinvertebrates collected by DWR during 2002.

Site Name:	Feather River										Glen Creek	
CDFG Site Code:	FR-DSH		FR-H162		FR-NMLP		FR-RR		FR-USH		GC-1	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Taxonomic Richness	17	0.21	19	0.19	18	0.20	19	0.06	14	0.21	23	0.14
Cumulative Taxa	26		29		27		27		20		32	
Percent Dominant Taxon	62	0.07	62	0.25	32	0.33	27	0.07	83	0.11	34	0.19
EPT Taxa	6	0.10	7	0.31	8	0.14	6	0.09	6	0.18	8	0.07
EPT Index (%)	25	0.25	26	0.44	72	0.18	69	0.13	5	0.72	42	0.20
Sensitive EPT Index (%)	1	0.68	1	1.04	4	0.40	7	0.25	1	0.70	29	0.43
Cumulative EPT Taxa	7		9		10		8		8		11	
Shannon Diversity	1.5	0.03	1.5	0.31	2.1	0.10	2.1	0.05	0.8	0.48	2.3	0.09
Tolerance Value	5.6	0.02	5.6	0.04	4.6	0.09	4.7	0.04	6.0	0.01	4.5	0.12
Percent Intolerant Taxa (0-2)	0	0.87	1	1.21	4	0.42	7	0.25	0	0.87	30	0.41
Percent Tolerant Taxa (8-10)	3	0.85	2	0.45	2	1.34	5	0.35	5	0.09	7	0.29
Percent Chironomidae	62	0.07	62	0.25	14	0.65	10	0.19	83	0.11	24	0.42
Percent Collectors	84	0.05	81	0.03	56	0.11	62	0.08	91	0.10	35	0.42
Percent Filterers	10	0.56	10	0.55	20	0.59	27	0.39	6	1.48	8	0.40
Percent Grazers	1	0.56	5	0.74	19	0.82	5	0.31	0	1.13	47	0.32
Percent Predators	5	0.26	5	0.25	4	0.61	6	0.76	3	0.17	10	0.39
Percent Shredders	0	-	0	1.73	0	-	0	-	0	-	0	1.73
Average Abundance (#/ sample)	3,502	-	4,567	-	4,214	-	16,527	-	8,497	-	6,524	-

Table A-3. Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye Main, Steep Main, Robinson Main, and Hatchery Riffle page 1)

Taxonomic Group			Site - Eye Main (RM 60.1)			Site - Steep Main (RM 61.0)			Site - Robinson Main (RM 61.9)			Site - Hatchery Riffle (RM 66.6)		
			Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Acari														
	Anasitsilidae		0	0	36	0	0	0	0	0	0	0	0	0
	Arreneuridae		0	0	0	0	0	0	0	0	36	0	0	0
	Hygrobatidae		0	208	72	0	0	19	0	0	72	19	72	67
	Lebertidae		28	64	1,092	0	108	664	56	175	180	523	756	402
	Oribatid		10,708	25,795	11,340	1,248	20,808	2,395	5,877	23,483	3,564	6,783	13,752	3,429
	Pionidae		0	0	24	0	0	0	0	0	0	0	0	0
	Sperchontidae		24	347	240	36	720	488	96	286	252	263	1,332	222
	Torrenticolidae		0	147	756	0	144	464	0	0	0	0	72	395
(juvenile)	Unknown		0	72	0	0	72	0	0	0	0	9	0	16
	Unknown		0	0	0	0	0	0	0	0	0	0	36	0
Order Collembola														
	Hypogastruidae		56	0	0	0	0	0	0	0	0	0	0	0
Order Coleoptera														
(larva)	Unknown		0	0	24	0	0	0	0	0	0	0	0	0
(adult)	Unknown		0	0	36	0	0	0	0	0	0	0	0	0
(larva)	Elmidae	*Optioservus*	0	0	0	0	36	0	0	0	0	0	0	0
(larva)	Elmidae	*Ordobrevia*	0	0	0	0	72	0	0	0	0	0	0	0
(larva)	Elmidae	*Zaitzevia*	0	0	0	36	0	0	0	0	0	0	0	0
(larva)	Elmidae		0	0	36	32	0	0	0	0	0	0	0	0
Order Diptera														
(larva)	Ceratopogonidae		0	0	24	0	21	0	0	0	0	0	0	16
(pupa)	Ceratopogonidae		0	0	72	0	36	0	0	0	0	0	0	0
(larva)	Chironomidae		5,444	8,565	18,972	3,892	17,100	2,747	2,581	10,421	1,692	19,179	30,924	1,475
(pupa)	Chironomidae		112	264	840	172	720	157	315	355	432	869	1,404	331
(larva)	Empididae	*Chelifera*	0	0	192	0	0	19	0	0	36	0	0	0
(larva)	Empididae		28	0	36	32	0	0	0	0	0	19	0	16
(larva)	Simulidae		16,320	4,912	27,144	19,628	12,816	3,504	15,629	7,523	3,888	8,257	37,872	1,193
(pupa)	Simulidae		1,876	264	1,764	2,364	828	213	2,837	131	1,260	871	5,364	0
(larva)	Tipulidae	*Antocha*	120	53	1,788	1,032	756	461	19	0	252	219	936	0
(larva)	Tipulidae		672	0	0	0	0	0	0	0	0	0	0	0
(pupa)	Tipulidae		0	96	96	0	0	69	0	0	0	0	0	0
(larva)	other		0	0	0	0	0	56	0	0	0	0	0	0
(adult)	other		316	403	300	268	648	1,128	277	224	504	361	720	357
(pupa)	other		0	0	0	32	0	0	0	0	0	0	0	0
Order Ephemeroptera														
(nymph)	Baetidae	*Acentrella*	164	11,696	144	36	13,824	4,563	35	7,168	2,556	113	648	4,479
(nymph)	Baetidae	*Baetis*	11,476	6,205	5,340	21,672	14,976	11,819	9,813	3,127	19,548	3,524	13,320	5,304
(nymph)	Ephemerillidae	*Serratella*	0	1,061	588	36	972	2,411	0	121	1,224	0	216	351
(nymph)	Leptoyphidae	*Tricorythodes*	600	1,072	72	176	144	2,168	21	0	432	195	216	572
(adult)	other		0	0	0	0	36	592	0	0	108	39	0	239
Order Hemiptera														
	Corixdae		0	0	492	0	36	187	0	21	216	0	0	388
	Macroveliidae		0	0	96	0	0	0	0	0	0	0	0	0
	Notonectidae		0	32	0	0	0	0	0	0	0	0	0	0

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye, Steep, and Robinson Main, and Hatchery Riffle page 2)

Taxonomic Group			Site - Eye Main (RM 60.1)			Site - Steep Main (RM 61.0)			Site - Robinson Main (RM 61.9)			Site - Hatchery Riffle (RM 66.6)		
			Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Lepidoptera														
(larva)	Pyralidae	*Petrophila*	156	192	0	64	180	0	0	108	0	0	0	0
(pupa)	Pyralidae		0	0	0	0	0	0	0	0	19	0	0	0
Order Odonata														
(naiad)	Coenagrionidae		0	0	0	0	0	19	0	0	72	0	0	0
Order Plecoptera														
(nymph)	Periodidae	*Isoperia*	0	0	36	100	36	0	0	33	0	0	0	0
Order Trichoptera														
(larva)	Brachycentridae	*Amiocentrus*	0	0	0	0	0	69	0	0	0	0	0	0
(larva)	Glossosomatidae	*Glossosoma*	904	171	336	180	324	144	1,400	144	252	609	108	307
(larva)	Glossosomatidae	*Protoptila*	0	21	0	0	0	0	0	0	0	0	0	0
(pupa)	Glossosomatidae		76	347	24	36	684	69	16	304	72	0	36	51
(larva)	Hydropsychidae	*Hydropsyche*	2,172	1,779	2,292	10,084	3,816	18,232	149	191	14,040	308	540	6,432
(larva)	Hydropsychidae	*Cheumatopsyche*	56	0	0	104	0	0	0	0	0	0	0	0
(pupa)	Hydropsychidae		0	509	312	0	252	56	0	0	180	0	0	51
(larva)	Hydroptilidae	*Oxyethria*	0	0	48	0	0	0	0	0	0	9	72	0
(larva)	Hydroptilidae	*Hydroptila sp.*	0	0	0	0	0	37	0	0	108	0	0	16
(larva)	Hydroptilidae		0	0	0	0	0	0	0	0	0	0	0	31
(pupa)	Hydroptilidae		0	32	0	0	0	88	0	0	144	20	0	0
(larva)	Lepidostomatidae	*Lepidostoma*	0	0	0	0	0	0	0	0	0	0	36	0
(larva)	Polycentropodidae		0	0	0	0	0	0	0	0	0	0	72	0
(larva)	Psychomylidae	*Psychomyia*	0	0	0	0	0	0	0	0	36	0	0	0
(larva)	Psychomylidae	*Tinodes sp.*	0	0	0	0	0	56	0	0	0	0	0	0
(pupa)	Psychomylidae		0	0	0	0	0	19	0	0	0	0	0	0
(larva)	Psychomylidae	*Rhyacophila sp.*	0	0	0	0	0	0	0	0	0	0	72	0
(adult)	Other		0	0	64	0	0	0	0	0	0	0	0	0
Order Amphipoda														
	Other		0	32	0	36	0	37	0	0	36	95	0	48
Order Aranea														
	Other		0	0	48	0	0	0	0	0	36	0	72	0

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye Side, Steep Side, Robinson Side, and Hatchery Ditch page 1)

Taxonomic Group			Site - Eye Side (RM 60.1)			Site - Steep Side (RM 61.0)			Site - Robinson Side (RM 61.9)			Site - Hatchery Ditch (RM 66.6)		
			Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Acari														
	Anasitsilidae		0	0	0	0	0	0	0	0	36	0	0	0
	Arreneuridae		0	0	0	0	0	24	0	0	0	0	0	0
	Hygrobatidae		0	0	0	0	72	64	0	0	105	0	0	144
	Lebertidae		88	272	371	0	1,147	488	48	468	589	14	41	1,936
	Oribatid		756	11,810	0	4,356	61,091	5,720	1,115	48,816	1,051	0	0	76,541
	Sperchontidae		64	491	197	36	637	376	108	756	287	3	99	645
	Torrenticolidae		0	20	0	36	421	368	0	36	36	0	0	0
(juvenile)	Unknown		0	36	57	0	0	40	0	0	48	0	0	72
	Unknown		0	0	0	0	0	0	0	0	0	0	41	71
Order Collembola														
	Hypogastruidae		0	20	0	24	0	0	0	0	0	8	0	0
Order Coleoptera														
(larva)	Unknown		0	36	40	0	0	0	0	0	0	0	0	0
(adult)	Unknown		0	0	56	0	0	0	11	0	45	25	24	0
(adult)	Curculionidae		0	0	0	0	72	0	0	0	0	0	0	0
(adult)	Dytiscidae		0	0	0	0	0	0	0	72	0	0	0	0
(adult)	Dytiscidae	*Liodessus*	0	0	0	0	0	0	0	36	0	0	0	0
(adult)	Dytiscidae	*Sanfilipodytes*	0	0	0	0	0	0	0	0	0	3	0	0
(larva)	Elmidae	*Optioservus*	40	36	0	0	0	0	0	0	0	0	0	0
(larva)	Elmidae	*Ordobrevia*	0	0	0	0	72	0	0	0	0	0	0	0
(larva)	Elmidae		0	0	0	0	0	0	0	0	24	0	0	0
(larva)	Hydrophilidae		0	0	0	0	0	0	0	0	0	3	0	0
(larva)	Staphylinidae		0	0	0	0	0	0	0	0	0	8	18	0
Order Diptera														
(larva)	Ceratopogonidae		0	0	0	0	0	0	0	216	0	0	0	0
(pupa)	Ceratopogonidae		0	0	0	0	0	0	0	0	45	0	0	72
(larva)	Chironomidae		1,140	10,691	11,960	4,908	27,139	872	1,566	27,612	577	2,999	11,960	10,151
(pupa)	Chironomidae		136	405	431	228	421	0	179	2,196	0	815	2,256	500
(larva)	Empididae	*Chelifera*	0	0	200	0	0	0	0	0	0	0	0	0
(larva)	Empididae		0	20	83	24	0	40	0	0	0	59	18	0
(pupa)	Empididae		0	0	0	0	0	0	0	0	0	0	24	0
(larva)	Ephydridae		0	20	0	0	0	0	0	0	0	0	0	0
(larva)	Psychodidae	*Pericoma*	0	0	0	0	0	0	0	0	0	0	18	0
(larva)	Simulidae		10,856	7,353	10,356	17,904	22,555	3,880	2,582	7,524	2,265	1,506	5,337	789
(pupa)	Simulidae		1,904	386	125	1,776	1,867	768	286	828	153	76	1,242	285
(larva)	Tipulidae	*Antocha*	508	131	116	1,260	573	208	252	72	292	257	59	0
(larva)	Tipulidae	*Tipula*	0	0	40	0	0	0	0	0	0	0	0	0
(pupa)	Tipulidae		0	0	0	0	72	0	0	72	24	0	0	72
(larva)	other		0	0	0	0	0	0	0	0	0	6	0	0
(adult)	other		12	131	169	276	352	0	341	2,016	588	433	483	143
(pupa)	other		0	0	0	0	0	0	39	0	0	0	0	0

Table A-3 (continued). Benthic macroinvertebrates collected from the Oroville Facilities study area during winter, spring, and summer 2002 by CSU-Chico. (Sites Eye Side, Steep Side, Robinson Side, and Hatchery Ditch page 2)

Taxonomic Group			Site - Eye Side (RM 60.1)			Site - Steep Side (RM 61.0)			Site - Robinson Side (RM 61.9)			Site - Hatchery Ditch (RM 66.6)		
			Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer	Winter	Spring	Summer
Order Ephemeroptera														
(nymph)	Baetidae	*Acentrella*	136	12,215	227	276	21,587	1,336	99	10,188	4,216	6	176	1,645
(nymph)	Baetidae	*Baetis*	12,432	9,949	11,839	28,224	16,851	18,544	12,151	5,328	13,192	526	4,348	37,645
(adult)	Baetidae		0	36	0	0	0	0	0	0	0	0	0	0
(nymph)	Ephemerillidae	*Serratella*	0	2,479	0	0	2,869	1,608	0	72	2,125	0	24	573
(nymph)	Leptoyphidae	*Tricorythodes*	1,616	804	0	336	0	3,072	84	648	2,284	0	0	17,047
(adult)	other		0	0	0	72	0	0	13	0	91	0	0	0
Order Hemiptera														
	Corixdae		0	144	0	0	0	16	0	144	632	0	0	143
	Macroveliidae		0	0	0	0	0	0	0	0	0	0	63	0
	Veliidae		0	0	0	0	0	0	0	0	60	0	0	0
Order Lepidoptera														
(larva)	Pyralidae	*Petrophila*	84	36	0	72	0	0	45	0	0	0	0	0
Order Plecoptera														
(nymph)	Periodidae	*Isoperia*	100	0	0	156	72	0	23	0	0	0	0	0
Order Trichoptera														
(larva)	Brachycentridae	*Amiocentrus*	0	0	0	0	0	0	0	0	0	0	0	72
(larva)	Glossosomatidae	*Apegatus*	0	0	41	0	0	0	0	0	0	0	0	0
(larva)	Glossosomatidae	*Glossosoma*	1,432	975	7,268	264	0	664	2,345	180	348	226	617	0
(pupa)	Glossosomatidae		288	563	88	96	72	0	184	1,008	84	16	137	0
(larva)	Hydropsychidae	*Hydropsyche*	5,228	2,368	65	26,460	2,728	15,584	613	288	7,097	11	0	6,501
(larva)	Hydropsychidae	*Cheumatopsyche*	0	36	0	72	0	0	0	0	0	0	0	0
(larva)	Hydropsychidae		0	20	0	0	0	0	0	0	0	0	0	0
(pupa)	Hydropsychidae		0	252	0	24	360	192	0	36	72	0	0	72
(larva)	Hydroptilidae	*Oxyethria*	0	0	16	0	0	0	0	72	0	3	0	141
(larva)	Hydroptilidae	*Hydroptila sp.*	24	236	0	0	72	0	0	72	45	0	0	216
(larva)	Hydroptilidae		0	0	32	0	0	48	0	0	0	0	0	0
(pupa)	Hydroptilidae		0	0	0	0	0	0	0	0	45	0	0	143
(larva)	Lepidostomatidae	*Lepidostoma*	0	0	708	0	0	0	0	0	0	17	24	0
Order Amphipoda														
	Other		12	20	0	0	0	16	23	0	36	0	0	720
Order Aranea														
	Other		0	0	80	0	0	16	36	72	0	0	0	0
Order Branchiopoda														
	Other		0	0	0	0	0	16	0	0	0	0	0	0

Table A-4. Aquatic macroinvertebrate abundance data sorted by order and family across 17 sites, with total abundance for each order underlined. Aquatic macroinvertebrates were collected by DWR during Fall 2002.

Taxonomic Group	Family/Order Subtotals	
	Number	Percent
Arthropoda		
Coleoptera	**531**	3.49%
Dytiscidae	**8**	0.05%
Elmidae	**488**	3.20%
Hydrophilidae	**1**	0.01%
Psephenidae	**34**	0.22%
Diptera	**5,195**	34.12%
Ceratopogonidae	**10**	0.07%
Chironomidae	**4,113**	27.01%
Chironominae	**69**	0.45%
Diamesinae	**1**	0.01%
Orthocladiinae	**101**	0.66%
Tanypodinae	**2**	0.01%
Empididae	**49**	0.32%
Muscidae	**2**	0.01%
Simuliidae	**667**	4.38%
Tipulidae	**181**	1.19%
Ephemeroptera	**4,341**	28.51%
Ameletidae	**4**	0.03%
Baetidae	**3,406**	22.37%
Caenidae	**2**	0.01%
Ephemerellidae	**190**	1.25%
Heptageniidae	**359**	2.36%
Isonychiidae	**1**	0.01%
Leptohyphidae	**348**	2.29%
Leptophlebiidae	**31**	0.20%
Hemiptera	**7**	0.05%
Corixidae	**7**	0.05%
Lepidoptera	**352**	2.31%
Pyralidae	**352**	2.31%
Megaloptera	**3**	0.02%
Corydalidae	**3**	0.02%
Odonata	**97**	0.64%
Coenagrionidae	**92**	0.60%
Cordulegastridae	**1**	0.01%
Gomphidae	**4**	0.03%

Table A-4 (continued). Aquatic macroinvertebrate abundance data sorted by order and family across 17 sites, with total abundance for each order underlined. Aquatic macroinvertebrates were collected by DWR during Fall 2002.

Taxonomic Group	Family/Order Subtotals	
	Number	Percent
Plecoptera	**106**	0.70%
Capniidae	**2**	0.01%
Chloroperlidae	**30**	0.20%
Nemouridae	**3**	0.02%
Perlidae	**36**	0.24%
Perlodidae	**34**	0.22%
Pteronarcyidae	**1**	0.01%
Trichoptera	3,491	22.93%
Brachycentridae	**246**	1.62%
Calamoceratidae	**2**	0.01%
Glossosomatidae	**31**	0.20%
Glossosomatidae	**5**	0.03%
Helicopsychidae	**17**	0.11%
Hydropsychidae	**2,426**	15.93%
Hydropsychidae	**1**	0.01%
Hydroptilidae	**472**	3.10%
Hydroptilidae	**37**	0.24%
Lepidostomatidae	**41**	0.27%
Leptoceridae	**5**	0.03%
Limnephilidae	**2**	0.01%
Philopotamidae	**168**	1.10%
Philopotamidae	**2**	0.01%
Psychomyiidae	**34**	0.22%
Rhyacophilidae	**2**	0.01%
Crustacea	**39**	0.26%
Chelicerata	**285**	1.87%
Annelida	**200**	1.31%
Mollusca	**374**	2.46%
Nematoda	**68**	0.45%
Tertastemmatidae	67	0.44%
Platyhelminthes	**138**	0.91%
Planariidae	138	0.91%
Total Organisms:	15,227	

APPENDIX B PLANKTON RAW DATA

Table B-1. Aquatic phytoplankton collected by DWR from the Oroville Facilities study area during Fall 2002.

		Lake Oroville							Afterbay	
Family Name	*Scientific Name*	A	Fish PO	N Forebay	S Forebay	NF	MF	S F	North	South
BACILLARIOPHYCEAE	*Achnanthes sp.*								2	
BACILLARIOPHYCEAE	*Asterionella formosa*		163		14	8			7	6
BACILLARIOPHYCEAE	*Aulacoseira granulata*	118			127	102	343		78	
BACILLARIOPHYCEAE	*Campylodiscus sp.*			1						1
BACILLARIOPHYCEAE	*Cyclotella sp.*		1		1				2	
BACILLARIOPHYCEAE	*Diatoma sp.*			12					5	
BACILLARIOPHYCEAE	*Diatoma vulgare*				18	66				
BACILLARIOPHYCEAE	*Fragilaria crotonensis*	21	11	1	8	20	2	20	4	3
BACILLARIOPHYCEAE	*Fragilaria sp.*			6	1				2	11
BACILLARIOPHYCEAE	*Melosira granulata*	130		38	23	80		123	3	33
BACILLARIOPHYCEAE	*Melosira Roeseana*									6
BACILLARIOPHYCEAE	*Navicula sp.*				1					
BACILLARIOPHYCEAE	*Synedra capitata*									1
BACILLARIOPHYCEAE	*Synedra ulna*				2	2				
BACILLARIOPHYCEAE	*Synedra sp.*			1	2			2	5	3

Table B-1 (continued). Aquatic phytoplankton collected by DWR from the Oroville Facilities study area during Fall 2002.

Family Name	Scientific Name	Lake Oroville							Afterbay	
		A	Fish PO	N Forebay	S Forebay	NF	MF	S F	North	South
CHLOROPHYCEAE	*Ankistrodesmus falcatus*								1	1
CHLOROPHYCEAE	*Botryococcus protuberans*		1							
CHLOROPHYCEAE	*Closteriopsis longissima*		1							
CHLOROPHYCEAE	*Coelastrum microporum*		1							
CHLOROPHYCEAE	*Elakatothrix viridis*								1	
CHLOROPHYCEAE	*Eudorina elegans*						1			
CHLOROPHYCEAE	*Microspora sp.*								6	
CHLOROPHYCEAE	*Mougeotia sp.*					3				6
CHLOROPHYCEAE	*Mougeotiopsis sp.*			2						5
CHLOROPHYCEAE	*Oocystis sp.*		19							
CHLOROPHYCEAE	*Pediastrum duplex*		1							
CHLOROPHYCEAE	*Pediastrum simplex*		1							
CHLOROPHYCEAE	*Scenedesmus quadricauda*		1							
CHLOROPHYCEAE	*Scenedesmus sp.*		1							
CHLOROPHYCEAE	*Schroederia setigera*					1				
CHLOROPHYCEAE	*Spirogyra sp.*			52		17				16
CHLOROPHYCEAE	*Ulothrix sp.*				9					4
CHLOROPHYCEAE	*Ulothrix subtilissima*		10							
CHLOROPHYCEAE	*Volvox sp.*					1		1		
CHLOROPHYCEAE	*Zygnema sp.*									6
CHRYSOPHYCEAE	*Dinobryon sertularia*				51	81			66	
CHRYSOPHYCEAE	*Dinobryon bavaricum*	18								
CHRYSOPHYCEAE	*Synura uvella*							5		
CRYPTOPHYCEAE	*Cryptomonas sp.*								1	
CYANOPHYCEAE	*Anabaena spiroides*									2
CYANOPHYCEAE	*Anabaena sp.*	3	187			1				
CYANOPHYCEAE	*Aphanizomenon flos-aquae*	125				107	5	4		
CYANOPHYCEAE	*Oscillatoria sp.*		4	6	19	28			24	41
DINOPHYCEAE	*Ceratium hirundinella*		23		1			2		
DINOPHYCEAE	*Glenodinium sp.*							1		
DINOPHYCEAE	*Glenodinium quadridens*		1							
EUGLENOPHYCEAE	*Phacus sp.*						642			
Unidentified	*Unidentified flagellates*								6	